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ECOLOGY OF SOIL FAUNA IN GRAZED AND CULTIVATED LANDS IN THE AREA OF LAKE NAIVASHA, KENYA

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ABSTRACT

Samples of soil fauna were collected from 5 sites by hand-sorting method in the area of Lake Naivasha, Kenya in summer 1989. Lake Naivasha is a fresh water Lake with grazing and irrigation of field crops at its shores. Five sites were selected, they are 3, 600, 3000, 4000, and 6000 m from the lake and denoted as 1,2,3,4, and 5. Site 1 and 2 are free grazing areas, while 3,4, and 5 are for carnation, potato and an ornamental cultivations respectively. Grazing sites are separated from the cultivated sites by a road of 10 m width. Fertilizers and pesticides were used in sites 3,4, and 5. Data were treated by multivariate statistical analysis : correspondence analysis and ascending heirarchic classification. Soil fauna extracted were earthworms, Lepidoptera larvae, ants, Carabidae, Tenebrionidae, Staphylinidae, spiders and ticks. Total population densities of soil animals were generally higher in cultivated areas than in the grazing ones, except for site 3, where carnation plants were at very early stage. Density of plant cover and intensity of agricultural practices as well as type of land use are the most important factors affecting density, biomass, and diversity of soil animals. Animal density and biomass were more affected by Cu, Mg, and Zn than by other soil factors.

RESUME

En ete 1989, des echantillons de la faune du sol ont ete collectionnes du rivage du Lac Naivasha par la methode de triage manuel. Le Lac d'eau douce permet le paturage pres du brod d'eau et l'agriculture irriguee un peu plus loin. Cinq sites ont ete choisi a 3, 600, 3000, 4000 et 6000 m du rivage et sont nommes 1,2,3,4, et 5 consecutivement. Les sites 1 et 2 sont de paturage, tandis que les sites 3,4, et 5 sont cultives de girofles, pommes de terre et une plante ornamentale, et sont separes des sites 1 et 2 par une route, et sujets a l'emploi des engrais chimiques et une des pesticides. Les donnees sur la densite des peuplements de la faune du sol ont ete traites par l'analyse des correspondances et la classification hierarchique ascendante. Les especes triees sont les vers de terre, chenilles de

lepidopteres, fourmis, carabides, tenebrionides, staphyilnides, araignees, et tiques. La densite de la faune etait en general plus elevee dans les agrosystemes que dans les systemes de paturage, sauf dans le site 3 ou les plantes n'etaient que de 15 cm de haut. La densite vegetale et l'intensite des pratiques culturales semblent les facteurs les plus importants a determiner la structure des peuplements de la faune du sol.

INTRODUCTION

Lasebikan (1988) in his review of soil fauna studies already carried out in Africa generally emphasized that our knowledge of soil fauna in Africa, South Africa excepted, is strikingly deficient due to long periods of neglect. Lavelle (1988) and Okwakol (1988) are of the same opinion except for studies on termites carried out in different parts of Africa.

In East Africa, knowledge on soil fauna is mostly derived from work done on termites which was reviewed by Okwakol (1988). Some studies are given to illustrate the composition of soil arthropods in East African countries such as works of Salt (1952, 1954, 1955 and 1987), Pomeroy and Rwakaikara (1975), Jago and Masinde (1968), Davis (1986) and Kairu (1986).

The role of invertebrates in humid tropical soils is still too little known (Davis, 1986 and Lavelle, 1988). Fragmentary results have been obtained on the important groups such as termites (Okwakol, 1988) and earthworms (Woomer and Ingram, 1990).

This work is an attempt to add to our knowledge of the ecology of soil fauna in grazed and nearby cultivated areas in Kenya, on the shores of Lake Naivasha.

MATERIAL AND METHODS

The study area is at the shores of Lake Naivasha, lat 0° 45 S, long 36° 30 E and alt. 1890 m.a.m.s.l. Lake Naivasha is a shallow fresh water lake in the eastern rift valley of Kenya (area about 162 km^2), at about 100 km north of Nairobi. AT the southh of the Lake Elsamere Conservation Centre is located, 20.5 km from the junction of Moi south Lake road with the Nairobi/ Nakuru road (Fig. 1). The Lake is important for its fisheries, irrigation, aquatic bird population and tourist value. It is surrounded by a highly fertile soil. Year round crops are achieved with irrigation from Lake water. Lake levels fluctuated extensively and more rapidly during the last decade than previously, causing vegetation changes. More recently, extensive

papyrus loss was attained following water level declines and agricultural clearance (Elsamere Conservation Centre, pers. comm.).

Description of Sites

Five sites constituting a transect away from the Lake shore in a SE directionn were selected for sampling soil animals (Fig. 1). These sites are :

Site 1: a Lake side area, 3 m from the lake shore.
Site 2: a Lake side area, 600 m from the lake shore.

Both sites 1 and 2 are free hrazing areas, located between the lake border and Moi south lake road, grazed by sheep, goats, cattle, and wild buffaloes as visitors. Vegetation consists of Euphorbia candelabra, Acacia albida, and A. xanthophoea trees and very short grasses in site 1 and tall grasses in site 2. Site 1 may have been under water in 1988.

Site 3: a field crop cultivated with carnation plantation at a very early stage. The height of plants was 15 cm. This site is 3000 m from the lake shore.

Site 4: a field crop cultivated with potato plantation at late stage just before harvesting. This site is 4000 m from the lake shore.

Site 5: a field crop cultivated with an ornamental plantation at stage before flowering. The height of plants was 50 cm. This siteis 6000 m from the lake shore.

N.P.K. (20-10-10) and T.S.P. (tri-sodium phosphate) fertilizers were added at a rate of 250 kg/faddan for sites 3, 4, and 5. Nemacure, Fuldon and Aldrin 40 % pesticides were added to the same sites (Kamere, pers. comm.).

Methods of Sampling Soil Fauna

Assessing the abundance and functional structure of soil macro-invertebrate communities in soil may be done with a smple and relatively non-time consuming method such as the hand-sorting method (Lavelle, 1988). Dynamic extraction techniques, which rely on the movements of animals as a response to physical or chemical stimuli, will be avoided because of their generally low efficiency in the conditions of tropical soils and their excessive selectivity (Lavelle, 1988).

Five samples were taken from each site. Quadrats (50 x 50 x 50 deep cm) were selected at random along a line within the centre

of the farm (between plants in order to avoid damaging the roots). Soil extracted from the excavated pit was examined and animals were hand-picked. Animals were preserved in 70 % ethanol (Anderson and Ingram, 1987). Samples were collected in August 1989, after July heavy rains and the beginning of summer season.

Soil samples were collected from each site for the determination of some variables (Table 1). Soil chemical analysis was carried out at the National Agricultural Laboratories, Department of Agriculture, Nairobi, Kenya. Identification of animal specimens was carried out at the Natural History Museum of Kenya (Nairobi), except for spiders which were kindly identified by Dr. V.I. Ovtsharenko (Leningrad).

Treatment of data

Data obtained in this study were examined by multivariate statistical methods : correspondence analysis CA and ascending hierarchic classification AHC. For detailed explantation of CA see Greenacre (1984) and for AHC see Roux (1985). The computer calculation for CA and AHC were carried out at Cairo University using the DATAVISION programme 1.2 (Roux, 1987) developed for APPLE IIe in BASIC, and allowing for the application of disjunctive coding method. This method comprises the categorization of data into groups or intervals. The number of categories varies according to the need for such study, ranging from 2 up to 5 categories with varying border as is desired. Disjunctive coding is a useful tool when dealing with different units and kinds of environmental conditions. This technique was used prior to the application of CA and AHC.

Absolute importance value (AIV) and relative imortance value (RIV) were calculated as described by Ghabbour and Shakir (1980). This method gives an assessment about the choice of variables according to which judgement can be made on the importance of various taxa of invertebrate soil animals. This method is based on density, biomass, and absolute frequency of an animal species.

RESULTS

Table 1 shows results of soil chemical analysis of some parameters for the 5 sampled sites. Fig. 2 shows the graphic representation of the application of CA and AHC ordination methods to the data of Table 1. 83 % of the variance is associated with the first (horizontal) axis and 9 % with the second (vertical) one. The density of plant cover and agricultural practices seem to be the most important factors in classifying sites. The first exis separates the density of plant cover and the high intensity of sgricultural practices at the right hand side of

the figure (sites 4 and 5) from low density of plant cover and lowest intensity of agricultural practices at the left hand side of the figure (site 1). Sites 2 and 3 lie inbetween, site 3 has carnation plantation at a very early stage (height of plants 15 cm) and the soil is therefore exposed. The other site 2, is a grazed area with a denser vegetation (taller grasses) than that of site 1.

TABLE 1. Soil chemical analysis of the 5 sites in the area of Lake Naivasha, Kenya, with upper limits of lower (L) and higher (H) classes.

	1	2	3	4	5	L	H
pH	6.8	6.9	7.4	7.2	7.2	6.9	7.4
Na m.e. %	0.32	0.32	0.32	0.47	0.54	0.32	0.54
K m.e. %	0.42	0.56	0.50	1.04	0.60	0.50	1.04
Ca m.e. %	1.6	2.6	2.0	2.0	1.6	1.6	2.6
Mg m.e. %	0.9	1.8	1.4	2.2	1.6	1.6	2.2
Mn m.e. %	0.40	0.37	0.42	0.50	0.37	0.40	0.50
P p.p.m.	3.0	3.0	3.0	3.0	3.0	-	-
OM %*	3.84	2.15	1.91	3.95	1.02	1.91	3.95
E.C.**	-	-	0.30	0.40	0.20	-	-
Fe p.p.m.	60.5	22.5	25.0	14.0	14.0	14.0	60.5
Cu p.p.m.	1.1	0.8	0.9	0.7	0.8	0.8	1.1
Zn p.p.m.	6.5	10.0	6.0	7.5	6.5	6.5	10.0
Grazing	+	+	-	-	-	0	1
Pesticides	-	-	+	+	+	0	1

* Organic matter
** Electric conductivity
\+ Present or used

The same data (Table 1) were used again, after classification by disjunctive coding into two classes (lower and higher values), for two purposes : firstly the classification of sites, secondly to illustrate the characteristics of each site. The upper limits of the lower and higher classes of these variables are shown in Table 1. The values for P and E.C. were not used. since P has a constant value for all sites and E.C. was measured only in sites 3, 4, and 5. Figure 3 shows the application of ordination methods to the classified factors. 46 % of variance is associated with the first axis and 32 % with the second one. Again, ordination separates the 5 sites according to the intensity of agricultural practices and density of plant cover. There are 3

groups : the first one at the right hand side of the figure, comprising sites 4 and 5, represents the highest intensity of agricultural practices and highest density of plant cover. This group is characterized by lower values of organic matter and Fe and higher values of Na and pH. In these two sites pesticides were used in a higher rate and there is no grazing. The second group, on the left hand side, comprising sites 1 and 3, represents minimum intensity of agricultural practices and minimum density of plant cover. Site 1 is subjected to free grazing with a lower density of Acacia albida trees and shorter grasses. This site is characterized by lower values of Na and pH and high values of Fe. Site 3 is a field cultivated with carnation plantation at a very early stage (height of plants about 15 cm) thus soil is exposed and with a very much lower plant density. This site is characterized by lower values of K, Mg, Zn and Ca and higher values of Mn and Cu. Pesticides were not used in these two sites and intensive grazing is associated with site 1. A third group is present at the middle of the figure, and seems to be intermediate in density of plant cover and lower intensity of agricultural practices. This group is characterized by lower values of Cu and Mn and higher values of Mg, K, Ca, Zn, and organic matter. Higher values of organic matter associated with this site may be due to the accumulation of plant litter and urine and faeces of the grzaing animals.

The soil macro-invertebrates of the 5 sites could be grouped into 13 species. The population density per square meter and taxonomic classification of these species are shown in Table 2. The total number of individuals for each site are in ascending order 4.8, 14.4, 20.8, 48.0, and 85.6 individuals/m^2 for sites 3, 1,2,4, and 5 respectively.

Figure 4. shows application of ordination methods to data of Table 2. 60 of variance is associated with the first axis and 18 % with the second one. The first axis separates higher (left side) from lower (right side) density of plant cover. The sites are separated and arranged along this axis. The second axis swparates the higher (at the end of axis 2) from lower (top of axis 2) intensity of agricultural practices. Site 1 respresent lower density of plant cover, some trees and very short grasses, nearer Lake Naivasha. Fauna associated with this site are the two spider species; Paradosa sp. and Araneus sp., the tick species; Boophilus annulatus and Rhipicephalus sp. and earthworms. In the middle of Fig. 4, is a group comprising sites 2, 4, and 5. Site 2 is subjected to free grazing, but with more trees and taller grasses than site 1. The other sites, 4 and 5, are cultivated fields. Site 4 is cultivated with potatoes at a very late stage, just before harvesting. Site 5 is cultivated with an ornamental plantation, the height of plants is about 50 cm, and at the

period before flowering. Species associated with these sites are ants; Monomorium sp. and Anergates atratulus and the Staphylinid Philoothus bestiolis. These two sites 4 and 5 have the largest total density of soil fauna among the 5 sites due to the higher

TABLE 2. Population density of soil fauna sampled in 5 sites in the area of Lake Naivasha, Kenya, as no./m².

N	F	Species	1	2	3	4	5
a	D	Earthworms	3.2±1.5	0.8±0.8	0	1.6±1.0	0
b	P	Lepidoptera larvae	0	0.8±0.8	0.8±0.8	0	3.2±1.5
		Formicidae	6.4±2.0	14.4±4.5	0	24.0±8.4	56.0±11.2
c	H	Monomorium sp.	5.6±2.4	12.0±3.6	0	19.2±6.6	51.2±10.3
d	A	Anergates atratulus	0.8±0.8	2.4±1.6	0	4.8±2.3	4.8±2.9
		Coleoptera	1.6±1.0	3.2±1.5	4.0±1.3	21.6±6.8	25.6±6.4
		Carabidae	1.6±1.0	0	2.4±1.0	11.2±4.8	16.8±5.1
e	C	Acupalus sp.	0.8±0.8	0	1.6±1.0	7.2±4.5	11.2±5.4
f	C	Hyparpalus sp.	0.8±0.8	0	0.8±0.8	4.2±2.2	5.6±3.0
		Tenebrionidae	0	2.4±1.6	1.6±1.0	8.8±4.6	8.8±3.2
g	D	Gonoephalum microlipenne	0	1.6±1.0	0.8±0.8	6.4±3.7	4.0±1.8
h	D	Zophosia sp.	0	0.8±0.8	0.8±0.8	2.4±2.4	4.8±2.3
		Staphylinidae					
i	C	Philoothus bestiolis	0	0.8±0.8	0	1.6±1.0	0
		spiders	1.6±1.0	0.8±0.8	0	0.8±0.8	0
		Lycosidae					
j	C	Paradosa sp.	0.8±0.8	0.8±0.8	0	0.8±0.8	0
		Araneidae					
k	C	Araneus sp.	0.8±0.8	0	0	0	0
		Tick	1.6=1.0	0.8=0.8	0	0	0.8±0.8
i	A	Boophilus annulatus	0.8±0.8	0.8±0.8	0	0	0.8±0.8
m	A	Rhipicephalus sp.	0.8±0.8	0	0	0	0
		Total Density	14.4	20.8	4.8	48.0	85.6

n=5, mean ± 1 SE, D = detritivore, H = herbivore, A = animal parasite
C= carnivore, P = plant parasite N = symbole of species,
F = functional group.

density of Monomorium sp., 19.2 individuals/m² for site 4 and 51.2 individuals/m² for site 5. Site 3, presents at the top of sxis 2, represents the low density of plant cover and intensity of agriculturalpractices. This site is used for carnation plantation, the plantsare at a very early stage. Preparation of land for cultivation affects to a great extent the density of soil animals. This sitehas the lower total density among sites

TABLE 3. Biomass (alcohol-preserved) of soil fauna in the 5 sites in the area of Lake Naivasha, Kenya, as g/m².

Species	1	2	3	4	5	W
Earthworms	2.05±0.96	0.51±0.51	0	1.02±0.63	0	0.64
Lepidoptera larvae	0	0.42±0.42	0.42±0.42	0	1.66±0.78	0.52
Formicidae	0.32±0.1	0.79±0.3	0	1.39±0.52	2.67±0.61	
Monomorium sp.	0.22±0.1	0.48±0.14	0	0.77±0.26	2.05±0.41	0.04
Anergates atratulus	0.10±0.1	0.31±0.21	0	0.62±0.3	0.62±0.38	0.13
Coleoptera	5.22±3.2	5.37±2.89	8.82±2.87	49.73±14.53	59.53±16.06	
Carabidae	5.22±3.2	0	7.46±3.12	35.04±14.33	52.19±15.1	
Acupalus sp.	2.24±2.24	0	4.48±2.7	20.16±12.6	31.36±15.12	2.80
Hyparpalus sp.	2.98±2.98	0	2.98±2.98	14.88±8.18	20.83±11.16	3.72
Tenebrionidae	0	2.23±1.42	1.36±0.88	8.42±4.43	7.34±2.64	
Gonoephalum microlipenne	0	1.73±1.08	0.86±0.86	6.91±4.00	4.32±1.94	1.08
Zophosia sp.	0	0.50±0.5	0.50±0.5	1.51±1.51	3.02±1.45	0.63
Staphylinidae						
Philoothus bestiolis	0	3.14±3.14	0	6.27±3.84	0	3.92
spiders	0.93±0.81	0.10±0.1	0	0.10±0.1	0	
Lycosidae						
Paradosa sp.	0.10±0.1	0.10±0.1	0	0.10±0.1	0	0.13
Araneidae						
Araneus sp.	0.83±0.83	0	0	0	0	1.04
Tick	5.46±3.43	3.21±3.21	0	0	0	
Boophilus annulatus	3.21±3.21	3.21±3.21	0	0	3.21±3.21	4.01
Rhipicephalus sp.	2.25±2.25	0	0	0	3.21±3.21	2.81
Total Biomass	13.98	10.40	9.24	52.24	67.07	

W = average individual weight in g

(4.8/m²). A group of 5 taxa associated with sites 4 and 5 with higher densities comprises : Lepidoptera larvae, two carabids; Acupalus sp. and Hyparpalus sp. and two Tenebrionidae; Gonoeophalum microlipenne and Zophosis sp. These taxa are the only taxa associated with site 3 but with lower densities.

Table 3 shows results of individual weight of collected specimens in g (alcohol preserved weight). It is noticed that the tick, Boophilus annulatus, has the highest weight (4.01 g) while the ant, Monomorium sp., has the lowest one (0.04 g). Generally the cultivated sites, 3,4, and 5, have larger total biomass than the grazing sites (1 and 2). Site 3, carnation field, has the lowest total biomass among the 5 sites (Table 3). Figure 5 shows results of the application of ordination techniques to data of Table 3. 59 % of variance is associated with the first axis while 32 % with the second one. The first axis separates grazing sites from agroeco-system sites, while the second axis separates site 1, the most nearer site to the lake, from site 2, 600 m distance from lake shore. The agroeco-system sites, site 3, 4, and 5 are more similar to each other, while the grazing sites, site 1 and 2, are separated from each other. Association of species with these sites is the same as in Fig. 4. Araneus sp. and Rhipicephalus sp. are separated away from the two groups as in Fig. 4.

Soil animals tend to make aggregation into higher clumps. This leads to either insignificant correlations between population density or biomass of each taxa and such variables, or misleading "significant" correlations. To overcome this difficulty, ordination methods are used to elucidate the pattern of these correlations. Factors of Table 1 were categorized into two classes, higher and lower, the upper limits of these two classes are shown in Table 1. Both population densities and biomass of soil taxa are then distributed among these two categories of variables by disjunctive coding method prior to the application of ordination methods. Figure 6 and 7 show results of the relationships of classified factors with population density (Fig. 6) and biomass (Fig. 7) of soil animals. The total variance of the two figures is 91 %. In Figure 6, 77 % of variance is associated with the first axis and 14 % with the second one, while in Fig. 7, 79 % of variance is associated with first axis and 12 % with the second one. It is noticed that three clusters of soil fauna are grouped and separated along the first axis, and are denoted as A, B, and C, the latter cluster is divided into two sub-clusters, denoted as C1 and C2 and separated along the second axis. The coordination of sol fauna and factors are summarized as follows :

Cluster-A : Characteristic of grazing sites with Araneus sp. and Rhipicephalus sp.

Cluster-B: grazing sites without pesticide applications, characterized by lower values of Na, Mg, K and pH and higher values of Cu and Fe. The associated species are earthworms, Paradosa sp. and Boophilus annulatus

Cluster-C: cultivated sites with pesticide applications, characterized by lower values of Cu and Fe and higher values of Ma, Mg, K and pH.

Sub-Cluster-C1: characterized by lower values of Mn, Ca, Zn and organic matter. The associated species are Lepidoptera larvae, Monomorium sp., Acupalus sp. and Zophosis sp.

Sub-Cluster-C2: characterized by higher values of Mn, Ca, Zn and organic matter. The associated species are Anergates atratulus, Gonoeophalum microlipenne and Philoothus bestiolis.

Soil fauna of cluster-B are more affected by Mn, Ca, Zn and organic matter and higher values of Na, Mg, K and pH. Fauna of cluster-C in general and of sub-Cluster-C2 in particular are more affected by higher values of Cu and Fe, while fauna of sub-Cluster-C1 are more affected by higher values of Mn, Ca, Zn and organic matter. Fauna of cluster-A are affected by all factors.

DISCUSSION

Collection of soil animals from the 5 sites in Lake Naivasha area gives an idea about the community structure of the soil fauna in the area. The most pronounced changes were those associated with spatial variations in habitat from grazed to cultivated areas. The latter had a more abundant fauna than the former, however, the grazing area itself was rapidly changing in plant cover near the water of the Lake.Cultivated areas had higher density of plant cover than the grazed areas. The total density and biomass of soil animals were higher in cultivated sites than in grazing ones (Tables 2 and 3). The effect of pesticides seems to be negligible at the time of collection of soil animals since it was at late stages in plants of sites 4 and 5, while site 3 is the lowest one probably because carnation plants were at an early stage.

The method of sampling seems to be one of the most important factors affecting results (Davis, 1986). Much of the work in soil zoology originally aimed at the extraction of a arge segment of fauna by a single method, one method will give an almost absolute estimate of one species or group and will give

at the most a rather poor relative estimate for another (Southwood, 1978). The hand-sorting method used in this study is suitable for coolecting soil macro-invertebrate (Lavelle, 1988). Other groups, such as Acari and Collembola, present in most soils (Davis, 1986 and Salt, 1987) were not sampled in this study.

The difference in percentages of both functional groups and higher groups seems to be one of the most important measures for the comparison between grazed and cultivated area. Figure 8 and 9 show differences in population density and biomass of functional and higher groups of soil animals in grazed and cultivated areas. Higher numbers and biomass of detritivores and animals parasites are in grazed areas, while higher numbers and biomass of carnivores are in the cultivated areas. Density and biomass of herbivores and plant parasites seem to be the same in both areas (Fig. 8). Animal parasites are the tick species and the formicid ant Anergates atratulus which parasitizes the ant Tetramorium caespitum (Wheeler, 1910 and Creighton, 1950; cited by Wilson, 1971). The tenebrionid beetle, Gonoephalum microlipenne is a detritivore species (dePury, 1968 and Frohlich and Rodewald, 1970), while the staphylinid Philoothus bestiolis is a carnivore (Wallwork, 1970). Number sand biomass of earthworms, Staphylinidae, spiders and ticks are higher in the grazed area, while Carabidae and Tenebrionidae are higher in the cultivated area. Formicidae and Lepidoptera larvae seem to be the same in both areas (Fig. 9). The formicid ants have the highest density in both grazed and cultivated areas,specially the free living ant Monomorium sp. (Wilson, 1971) which has nearly similar density in both areas, while the parasitic ant, A. atratulus has slightly higher density in the grazed area. Lavelle (1983) suggests that the social insects are little affected by soil moisture, thus, ants are present in higher densities in all sites except site 3, since it is in the beginning of cultivation of carnation plant.

Soils of Lake Naivasha area are neutral. The mineral contents are generally low, since high temperature and moisture conditions prevailing in the tropics favour intense leaching (Lavelle, 1984). Organic matter seems to be low, since the process of humification is very rapid leading to the leaching of hydrosoluble fractions into deeper layers (Lavelle, 1984). The most important minerals that affected soil fauna in Lake Naivasha sites seem to be Cu and Zn. Higher Cu concentration seem to have caused decreased numbers and biomass of earthworms (Paoletti et al, 1988). Paoletti et al, (1988) reported that in old orchards spread with Cu fungicides, earthworm reproductive capacity and body growth are lowered. This may explain the presence of

earthworms in high numbers only in the grazing area. Zinc and copper concentrations also affect spiders and ticks.

The application of AIV and RIV method as described by Ghabbour and Shakir (1980), shows the arrangement of taxa of soil fauna in order of importance according to the combination of density, frequency and biomass (Fig. 10). According to AIV method, the top 5 important taxa in the grazed area are : Monomorium sp., earthworms, Boophilus annulatus, Gonoeophalum microlipenne and Anergates atratulus. In cultivated area, on the other hand, the top 5 taxa are : Acupalus sp., Hyparpalus sp., Monomorium sp., G. microlipenne and Zophosis sp. According to RIV method, the top 5 important taxa are the same in both grazed and cultivated areas but with different arrangement. Generally, the most important species in Lake Naivasha area are : Acupalus sp., Monomorium sp., Hyparpalus sp., G. microlipenne and Zophosis sp. according to AIV method, the same taxa with different arrangement but including A. atratulus instead of Zophosis sp. according to RIV method. Earthworms have the seventh order in both AIV and RIV. It is noticed that taxa from 1 to 6 belong to ants and Coleoptera. Generally, the most dominant groups in the tropical soil communities are ants, Coleoptera and earthworms (Swift et al., 1979 and Lavelle, 1984).

Soil animals density and biomass showed clearly a decrease that could be related to the mechanical and/or chemical treatment of the soil.

Density of plants is one of the most important factors which affect soil animal density and biomass in Lake Naivasha area. A dense plant cover protects soil from solar heating, creating conditions suitable for soil animals.

Mineral content of the soil of Lake Naivasha area seems to have a minor effect on soil animal except in a few cases such as copper and zinc.

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بيئة حيوانات التربة فى الأراضى الرعوية والزراعية فى منطقة بحيرة نيفاشا بكينيا

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جمعت حيوانات التربة فى صيف عام ١٩٨٩ بطريقة الانتقاء اليدوى من خمسة مواقع فى منطقة بحيرة نيفاشا بكينيا، بحيرة نيفاشا بحيرة مياه عذبة تستخدم فى رى الحقول المنزرعة بجانبها، تباينت مواقع الدراسة من حيث استخدام الأرض : المواقع ١ و ٢ أراضى رعى تبعد عن البحيرة مسافة ٣ و ٦٠٠ متر على الترتيب، بينما المواقع ٣ ، ٤ ، ٥ أراضى زراعية يزرع فيها القرنفل والبطاطس ونوع من نباتات الزينة وتبعد مسافة ٣٠٠٠ و ٤٠٠٠ و ٦٠٠٠ مترا عن البحيرة على الترتيب. يفصل بين مواقع الرعى والزراعة طريق يبلغ عرضه نحو ١٠ أمتار. اضيفت المخصبات الزراعية ومبيدات الافات الى الأراضى الزراعية، وذلك قبل أخذ عينات حيوانات التربة. عولجت البيانات احصائيا بواسطة التحليل الاحصائى المتعدد المتغيرات مثل التحليل التوافقى والتقسيم الهيراركى

عشائر حيوانات التربة الناتجة هى : ديدان الأرض - النمل - يرقات حرشفيات الأجنحة - الخنافس المفترسة - الظلاميات - العناكب - القراد أهم العوامل المؤثرة على الكثافة والتنوع الحيوانى فى هذه المنطقة هى كثافة الغطاء النباتى ودرجة تكثيف المعاملات الزراعية ونوع استخدام الأرض. فى المواقع الزراعية ذات الكثافة النباتية العالية يزداد تنوع وكثافة أعداد حيوانات التربة، حيث بلغت ٤٨ فرد/م٢ فى الموقع (٤) ونحو ٨٦ فرد/م٢ فى الموقع (٥)، كما أن الحيوانات التى تسود بها هى النمل - يرقات حرشفيات الأجنحة - الخنافس المفترسة - الظلاميات. تقل كثافة اعداد حيوانات التربة فى المواقع الرعوية، حيث بلغت نحو ١٤ فرد/م٢ فى الموقع (١) ونحو ٢١ فرد/م٢ فى الموقع (٢)، حيث تنخفض بها كثافة الغطاء النباتى وبلغت كثافة اعداد حيوانات التربة فى الموقع (٣) نحو ٥ فرد/م٢ وذلك لأن الزراعة كانت فى البداية ،حيث بلغ طول النباتات نحو ١٥ سم فقط. درست العلاقة بين العوامل المقدرة فى التربة وكثافة اعداد الحيوانات ووزنها وتبين انهما يتاثران أكثر بتركيز النحاس والخارصين والماغنسيوم

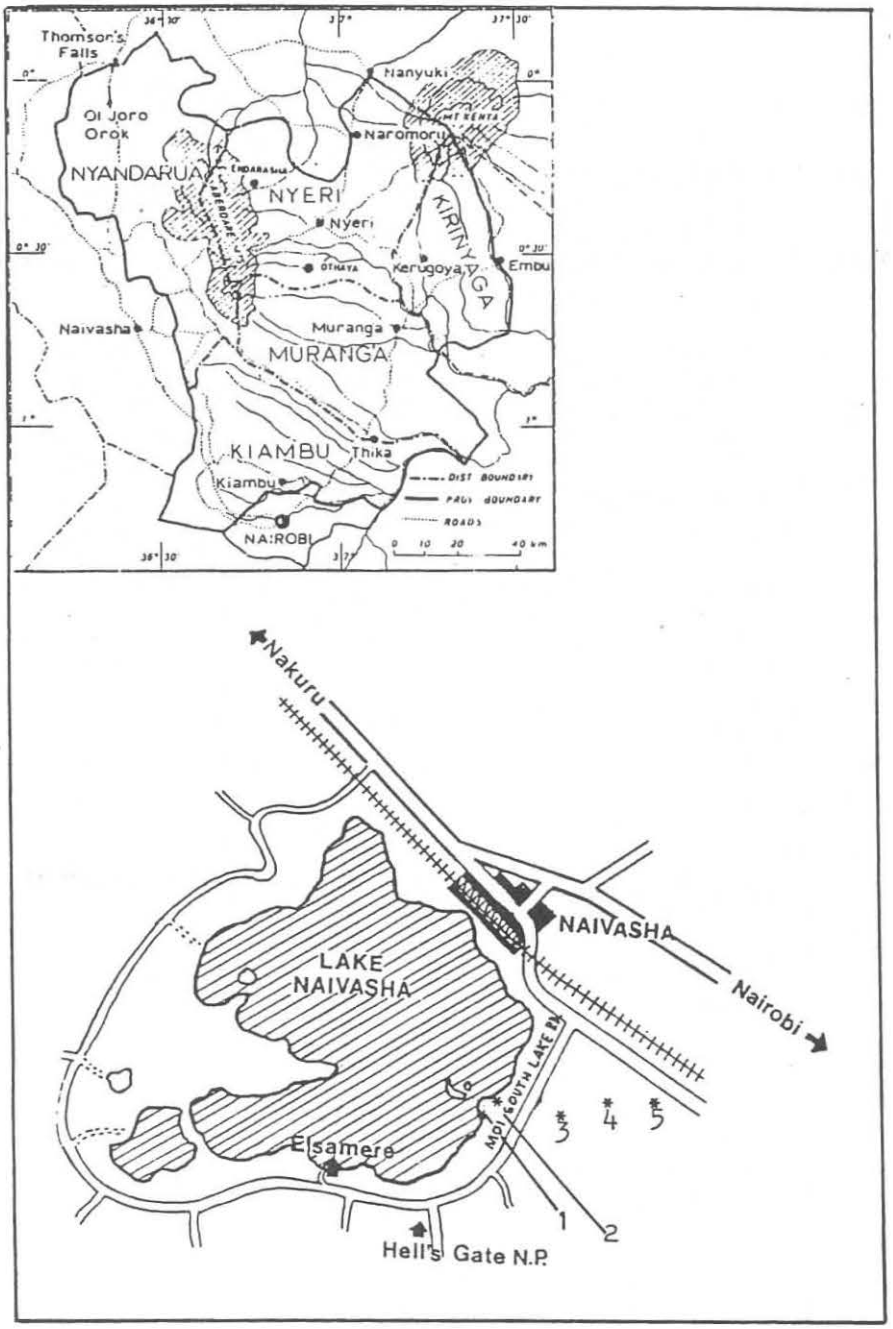


Fig. 1. Map of Lake Niavasha area, Kenya.

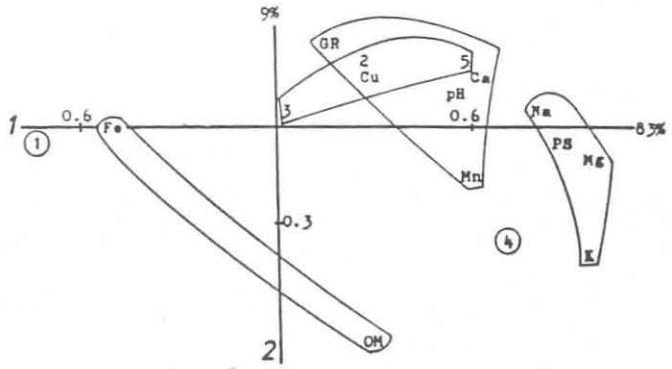


Fig. 2. Graphic representation of the results of ordination by CA method and the result of groupings by AHC method to the data of Table (1). without disjnctive coding. Symbols : GR = grazing, PS = pesticides application OM organic matter, sites (1-5) and chemical symbols as in Table 1.

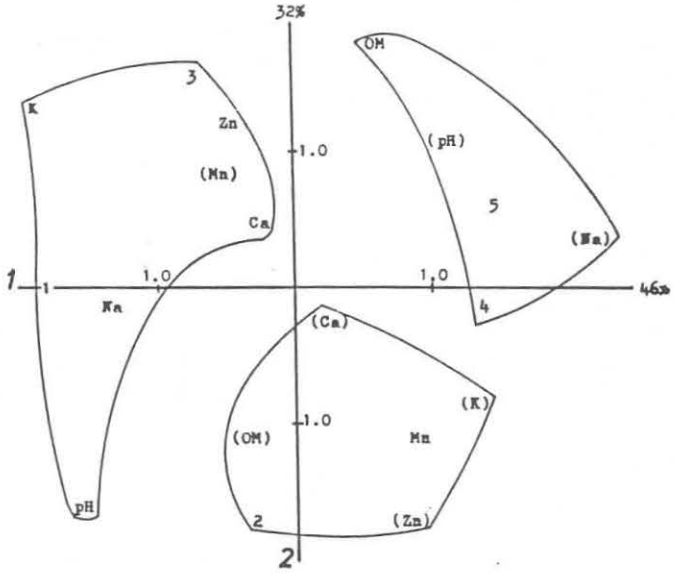


Fig. 3. Graphic representation of the results of ordination by CA method and the result of groupings by AHC method to classified data (by disjunctive coding) of Table 1.
Symbols : symbols between brackets are higher classes of variables, symbols without brackets are lower classes of the same variables. (Cu) and Mg are with K; PS is with (pH); Fe is with(Na); (Fe)is with Na; (Mg) and Cu are with (K); GR is with pH.

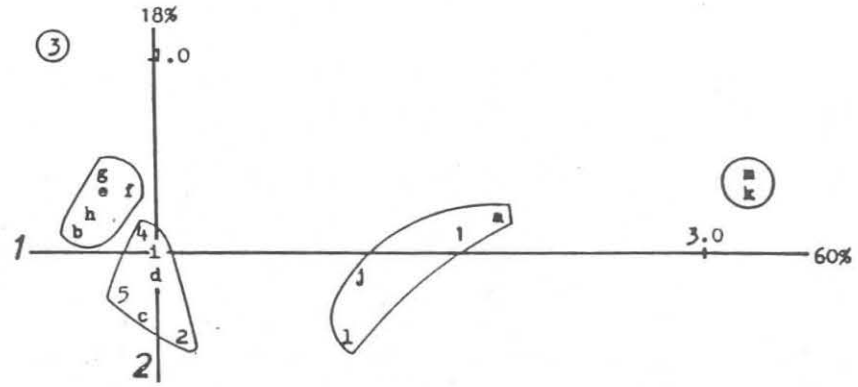


Fig. 4. Graphic representation of the results of ordination by CA method and the result of groupings by AHC method to population density of soil fauna (daya of Table 2.)
Symbols : sites (1-5) and species (a-m) as in Table 2.

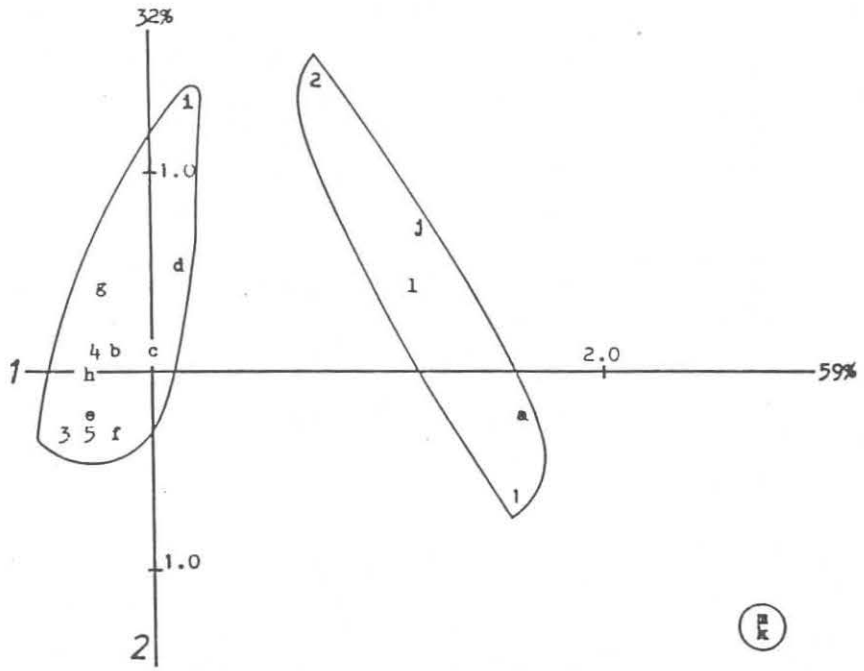
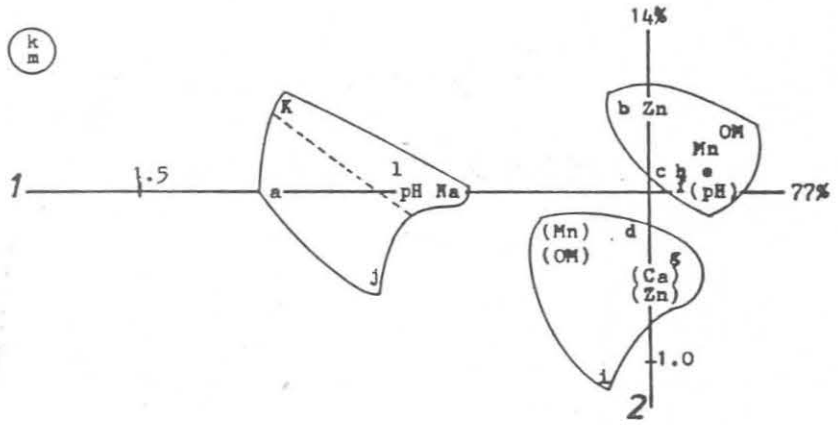
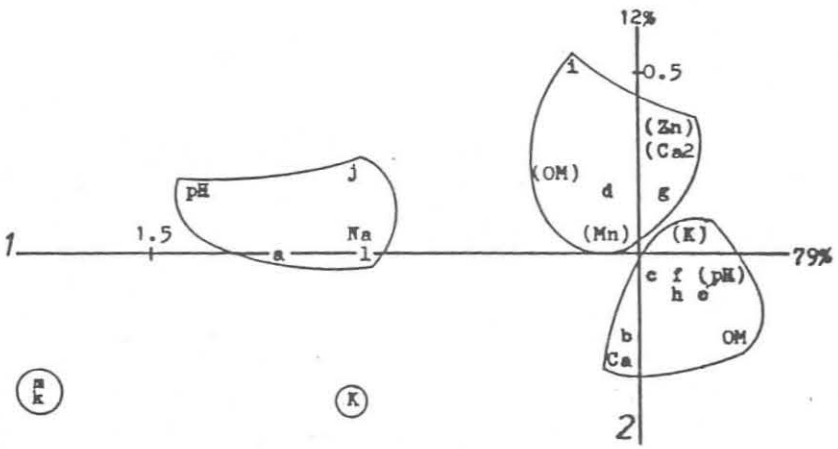


Fig. 5. Graphic representation of the results of ordination by CA method and the result of groupings by AHC method to the biomass of soil fauna (g/m^2), data of Table (3).
Symbols : as in Fig. 4.



ig. 6. Graphic representaion of the results of ordination by CA method and the result of groupings by AHC method to the data of Tables (1 and 2) using disjunctive coding. (CU) and Mg are with K; Ca with b; GR is with pH; (Fe) is with Na; (Na), (Mg), PS, (K), Fe and Cu are with (pH).



7. Graphic representation of the results of ordination by CA method and the result of groupings by AHC method to the data of Tables 1 and 3 using disjunctive coding.
GR is with pH; (Fe) is with Na; (Mg) and Cu are with (K); Mn is with f; (Na), PS, Fe are with (pH); Zn is with Ca; Mg and (Cu) are with K.

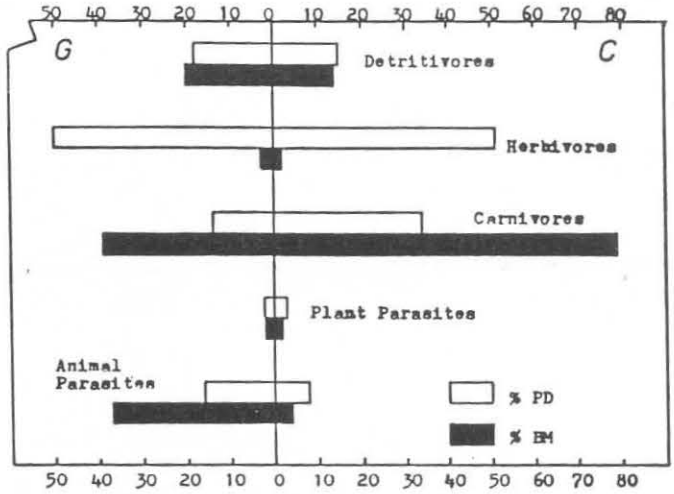


Fig. 8. Comparison of population density (PD/m²) and biomass (BM/m²) of functional groups in grazed (G) and cultivated (C) areas.

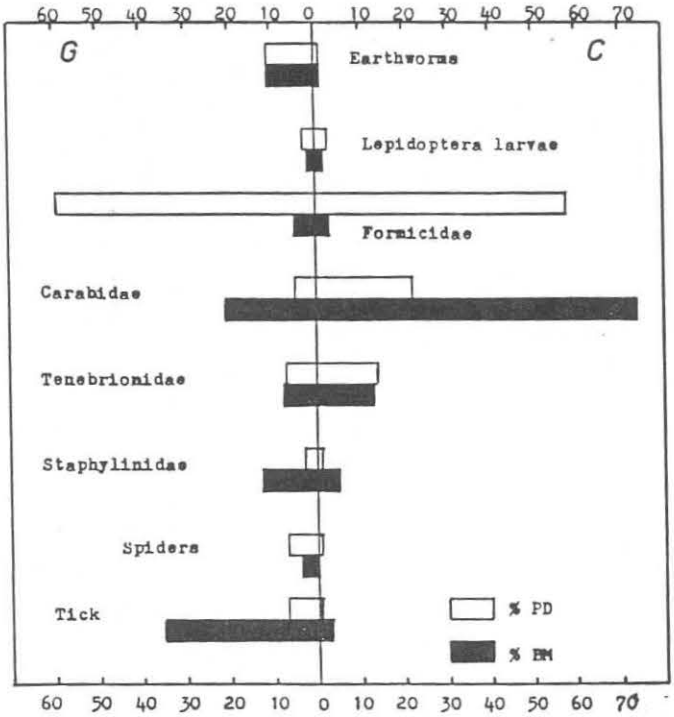


Fig. 9. Comparison of population density (PD/m²) and biomass (BM/m²) of higher groups in grazed (G) and cultivated (C) areas.

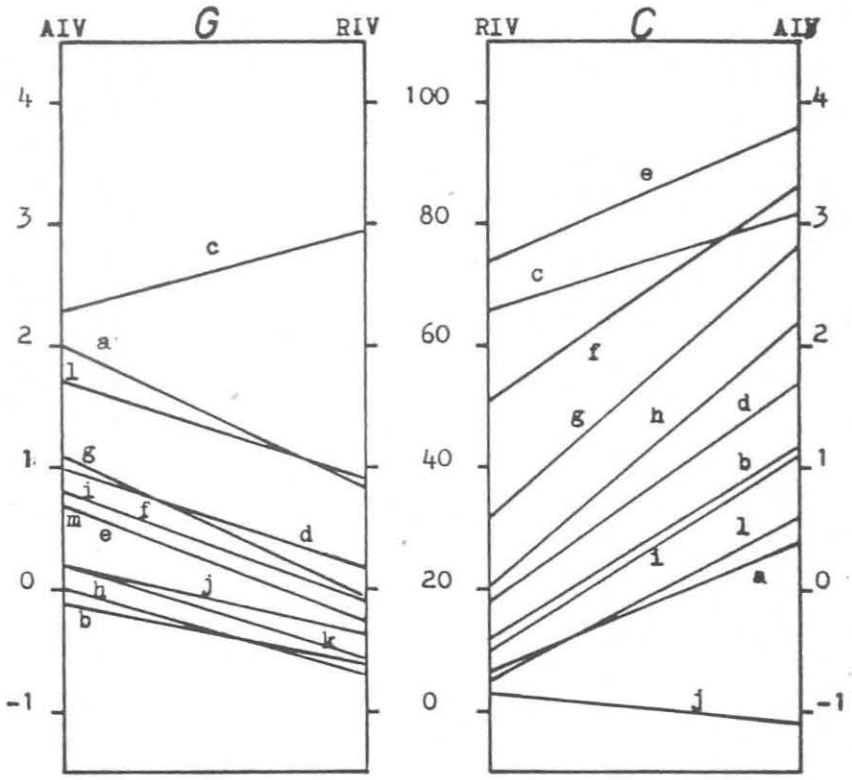


Fig. 10. Position of taxa on the Absolute Importance Value (AIV) and Relative Importance Vale (RIV) for grazed (G) and cultivated (C) areas.